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MINING PRACTICES, METHODS, AND COSTS AT MINE NO. 5 OF THE MARQUETTE RANGE, MICHIGAN

BY

W. W. GRAFF

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MINING PRACTICES, METHODS, AND COSTS AT MINE NO. 5 OF THE MARQUETTE RANGE, MICHIGAN[1]

By W. W. Graff[2]

INTRODUCTION

This paper describing the mining practice at Mine No. 5 of the Marquette range, Michigan, is one of a series being prepared by the Bureau of Mines on mining practices, methods, and costs in the various mining districts of the United States.

The top-slicing system of mining has been used ever since the present operating company took control of the property in 1903, the main level and sublevel layout being changed only as local conditions required and the use of mechanical equipment increased.

The mine is on the eastern end of the Marquette range, at Negaunee, in the Upper Peninsula of Michigan.

ACKNOWLEDGMENTS

The author is indebted to G. R. Jackson, general superintendent, and Carl Brewer, chief engineer, of the Cleveland-Cliffs Iron Co., for assistance in preparing this paper.

HISTORY

The place where iron ore was first discovered in Michigan in 1845 lies about 1¼ miles west of Mine No. 5. The numerous outcroppings of iron ore and iron formation adjacent to and west of the original discovery drew the attention of the early miners away from the vicinity of Mine No. 5, where glacial drift up to 200 feet in depth covered the entire ore body. It was not until 1883 that the ore body was discovered by diamond drilling. A shaft was sunk soon afterward, and the property has been worked continuously ever since, the first shipment of ore being made in 1887. The total shipments from the mine to January 1, 1930, were 11,704,256 long tons. The mine passed into the hands of the present operators in 1903.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6380."

2 - One of the consulting engineers, U. S. Bureau of Mines.

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GEOLOGY

The ore body lies in a large syncline dipping about 15° to the west, the ore coming to ledge at the east end of the trough. The ore occurs in the Negaunee formation of the middle Huronian age, which consists of ferruginous cherts and slates through which intrusions of diorite have occurred. Although these intrusions of diorite have an important bearing on the formation of ore on the range they are not important in this ore body. Some faulting has taken place along the diorite intrusions, or dikes as they are called locally, and also there are other faults known to exist across the formation. These faults do not complicate either mining or development of the ore body. The footwall consists of jasper underlain with Siamo slate; the hanging wall is jasper and ferruginous chert.

The ore body is quite regular, being about 100 feet in thickness in the middle of the syncline, thinning out toward both sides of the fold. It ranges from 400 to 800 feet in width, the average being about 600 feet. The footwall is quite uniform in dip and strike, but irregular lenses of ore often extend 50 to 75 feet up into the overlying jasper hanging wall.

PHYSICAL CHARACTERISTICS OF ORE AND INCLOSING ROCKS

The ore is a high-grade soft hematite. Two grades of ore are produced, Bessemer and non-Bessemer, the former averaging 55.96 per cent iron natural, 0.043 per cent phosphorus natural, and 5.10 per cent silica natural; the latter, 52.67 per cent iron natural and 6.24 per cent silica natural. Moisture averages 11.75 per cent. The ore is easily drilled and breaks into a fine aggregate, easily handled by scrapers. Near the hanging wall seams of hard blue ore occur, but these are drilled readily by auger drill machines. This harder ore breaks into large chunks, which occasionally have to be reduced by sledging to 8 inches in size. The intervening dikes are quite soft, but as a rule do not break into fines, so that if reasonable care is exercised this material can be prevented from contaminating the ore. The overlying jaspers range from soft to quite hard and on caving break into coarse rubble.

SHIPPING FACILITIES

The mine is served by two railroads, over which the bulk of the ore is shipped 13 miles to Marquette, on Lake Superior; thence it is taken by boat to lower lake ports. About 16 per cent of the annual production is sent by all-rail shipments to furnaces in Michigan and Wisconsin.

METHOD OF PROSPECTING AND EXPLORATION

The original ore body was disclosed by diamond drilling from the surface. The limits of the ore body are so well known that for the last 20 years the only exploration has been the development at depth of additional levels which can be planned in advance.

METHODS OF SAMPLING AND ESTIMATION OF TONNAGES AND VALUES

The sampling follows the standard method adopted by the Lake Superior mining companies and is described in "The Iron Ores of Lake Superior" by Crowell

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& Murray, Inc. 1927. On the surface a sample from each skip hoisted determines the grade of the daily output. Underground chute and level samples are taken by an experienced sampler when the motor train reaches the shaft station. A standard scoop $1\frac{1}{2}$ by $2\frac{1}{2}$ by $3\frac{3}{4}$ inches is used. Two scoopfuls are taken from each 4-ton car, one of which is placed in the bag representing the chute, the other into the box representing the level samples. Daily grab samples are taken from those working places where there is reason to question the grade of ore being mined. The breasts of the remaining working places have a similar grab sample taken once or twice a week.

The estimation of tonnages is made by volume, assuming 12 cubic feet of ore in place equals 1 ton. A division of the tonnage into Bessemer and non-Bessemer grade is quite difficult to make accurately. Bessemer ore is found only near the hanging wall in certain parts of the mine. The estimates of Bessemer ore are based on a knowledge of the past history of the property together with the information gained as new sublevels and territory are opened up in the regular course of mining operations.

The method of determining the value of the ore produced involves too long a discussion for this paper but can be found in detail in the book "The Iron Ores of Lake Superior" mentioned above.

METHODS OF DEVELOPMENT AND MINING

The property has been developed from three vertical shafts. The first shaft was sunk directly in the ore body in the early days and was abandoned many years ago. The second shaft was sunk in the foot wall toward the eastern end of the deposit and is now used for ventilation purposes. The present shaft is located on the south footwall of the deposit and was completed in 1912. It is 1208 feet deep; the upper 945 feet is concrete, circular in shape, 17 feet in inside diameter, and equipped with steel sets spaced at 10-foot intervals. The lower 263 feet is rectangular, is 10 feet 10 inches by 14 feet 10 inches in inside dimensions, and is equipped with wooden sets at 6-foot centers. This shaft was sunk in the following way: An 8 by 8 foot raise was put up from the 9th level at the end of a 2,000-foot rock drift 738 feet to a ledge where a 60-foot test pit had been sunk through surface material. After the raise had holed to the test pit the latter was enlarged to a sufficient size to accommodate the forms for the circular concrete collar. When that part of the shaft through surface was completed the work of stripping down the rock section and concreting was commenced, the waste material being handled through the raise to the 9th level, while the concrete, steel, etc. were lowered from surface. Sections of shaft about 50 feet in length were stripped and concreted at one operation. From winzes sunk in the ore body drifts were driven to the shaft site on the 10th, 11th, and 12th levels. Vertical raises holed to the bottom of the shaft. These were afterwards stripped to the full shaft size. The bottom 110 feet was sunk by ordinary shaft-sinking methods.

The change from the circular to the rectangular shape was made for several reasons. The added strength of the circular design was not needed, and the speed of sinking was increased. Furthermore, concreting the rectangular shaft did not require any special forms, as the steel sets were so designed that the 2-inch wooden lath took the part of a form, and part of the wall and end

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plates of the sets were anchored in the concrete. The cost of construction was decreased materially by this change in size and method of concreting. Figure 1 shows the plans of both the circular and rectangular portions of the shaft.

The ore body was developed in the early days by levels at intervals from 50 to 100 feet, but since the present company took control the main-level interval has been 100 feet. The early mining was by the room-and-pillar method, with the square-set form of timbering. The present company inaugurated the top-slicing system of mining in 1904 and for several years the old rooms and pillars were a distinct handicap in operation of the mine, many of the rooms being filled with sand from surface caves.

METHOD OF MINING

The system of mining used is sublevel top slicing. Parallel main-level crosscuts are driven at 150-foot centers across the ore body from a foot-wall drift. Through rock the main levels are untimbered and are about 8 by 10 feet in size. Through the ore and the soft rock the drifts are timbered with 8-foot caps and 8-foot legs, the latter having a batter of 2 inches to the foot. The main-level sets are treated with zinc chloride, and this treated timber lasts three times as long as untreated timber. Both the back and sides of the drifts are closely lagged.

Along the crosscuts 2-compartment cribbed raises, each compartment 4 feet 2 inches square inside, are put up at an angle of 65 to 70° on 35-foot centers. This layout provides for sublevel pillars 35 by 75 feet on each side of each raise; these are mined by one straight drift and two side slices. Along the foot wall and under the hanging wall it is not always possible to lay out the regular interval pillars, so it is often necessary to mine pillars of larger extent from one raise. Figure 2 shows a typical main level, Figure 3 a typical sublevel, while Figure 4 is a cross section showing mined slices and general geological structure.

The ore body stands up very well in most of the mine, so that the main levels and raises do not as a rule require much repair work. In some parts, however, considerable pressure develops as much as 100 feet below the actual mining elevation. In this territory it is exceedingly difficult to maintain main-haulage drifts, and a large amount of repair work is necessary.

The sublevel plan, as outlined above, is very satisfactory for the use of scrapers, as only one set-up of the hoist is required for taking the three slices on each side of the raise. The pillars are of such size that all the ore can be mined without an undue amount of pressure being developed before the ore near the raises is extracted. There are parts of the mine where it is often necessary to retimber around the raise before all the ore can be mined, but these places are in the minority. On each sublevel the tops of the raises are connected by drifts for handling timber, for ventilation, and for safety. The sublevel drifts are all timbered, using 8-foot legs and caps set at 5-foot centers. After a breast is blasted the back is carefully trimmed to the mat above, and at least three forepoles 5 or 6 inches in diameter are put in with a covering of lagging immediately beneath the overlying mat. These forepoles and lagging protect the miners from material falling from the mat while cleaning out the cut and putting in the next set. As an added precaution in all breasts

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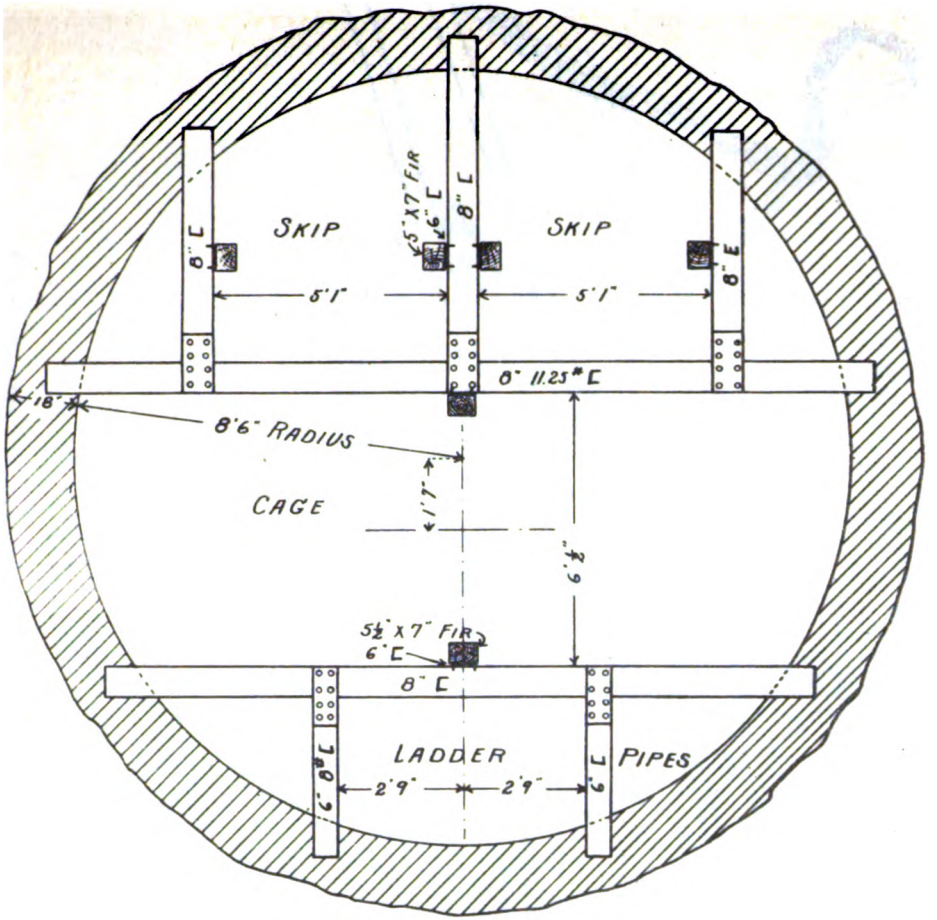
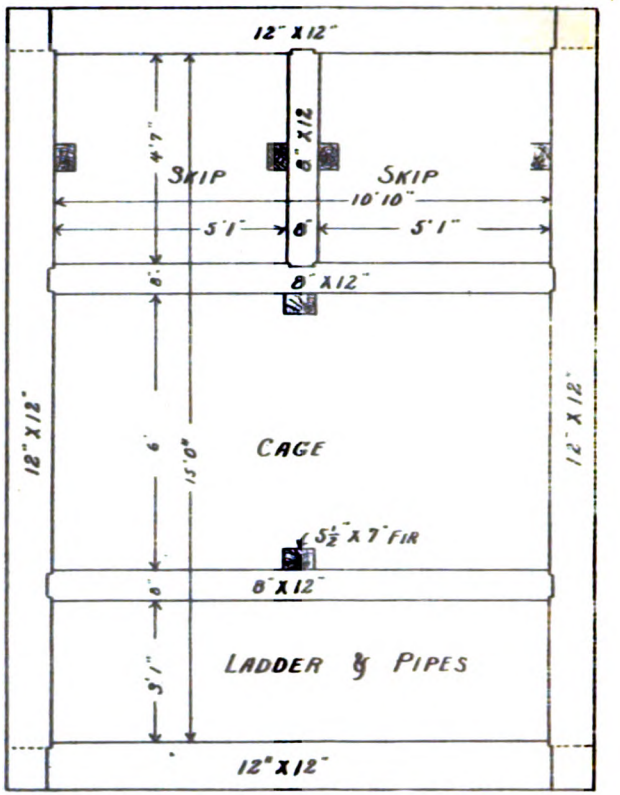


CIRCULAR SECTION



RECTANGULAR SECTION

Figure 1.- Plan of shaft

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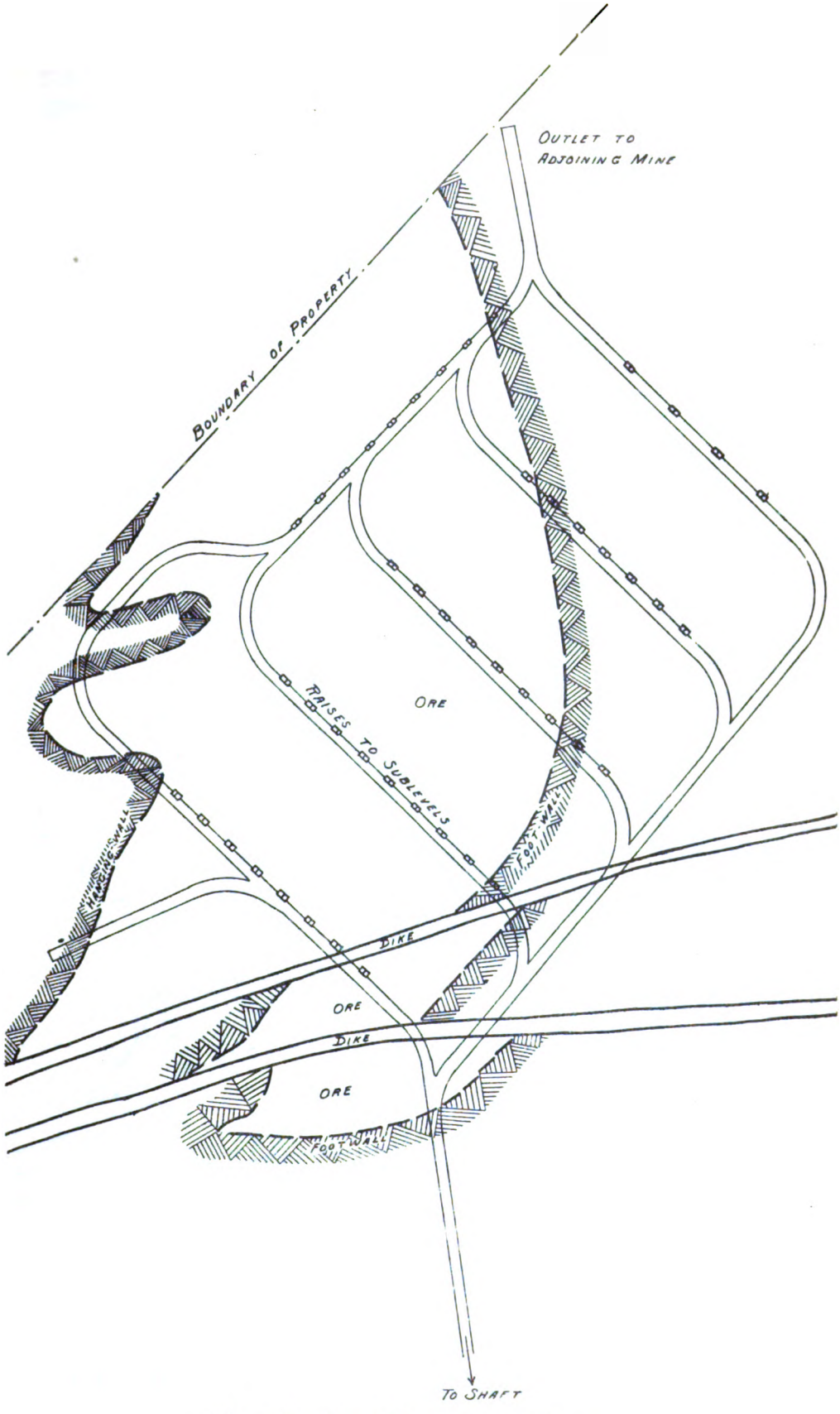

Figure 2.- Plan of typical main level

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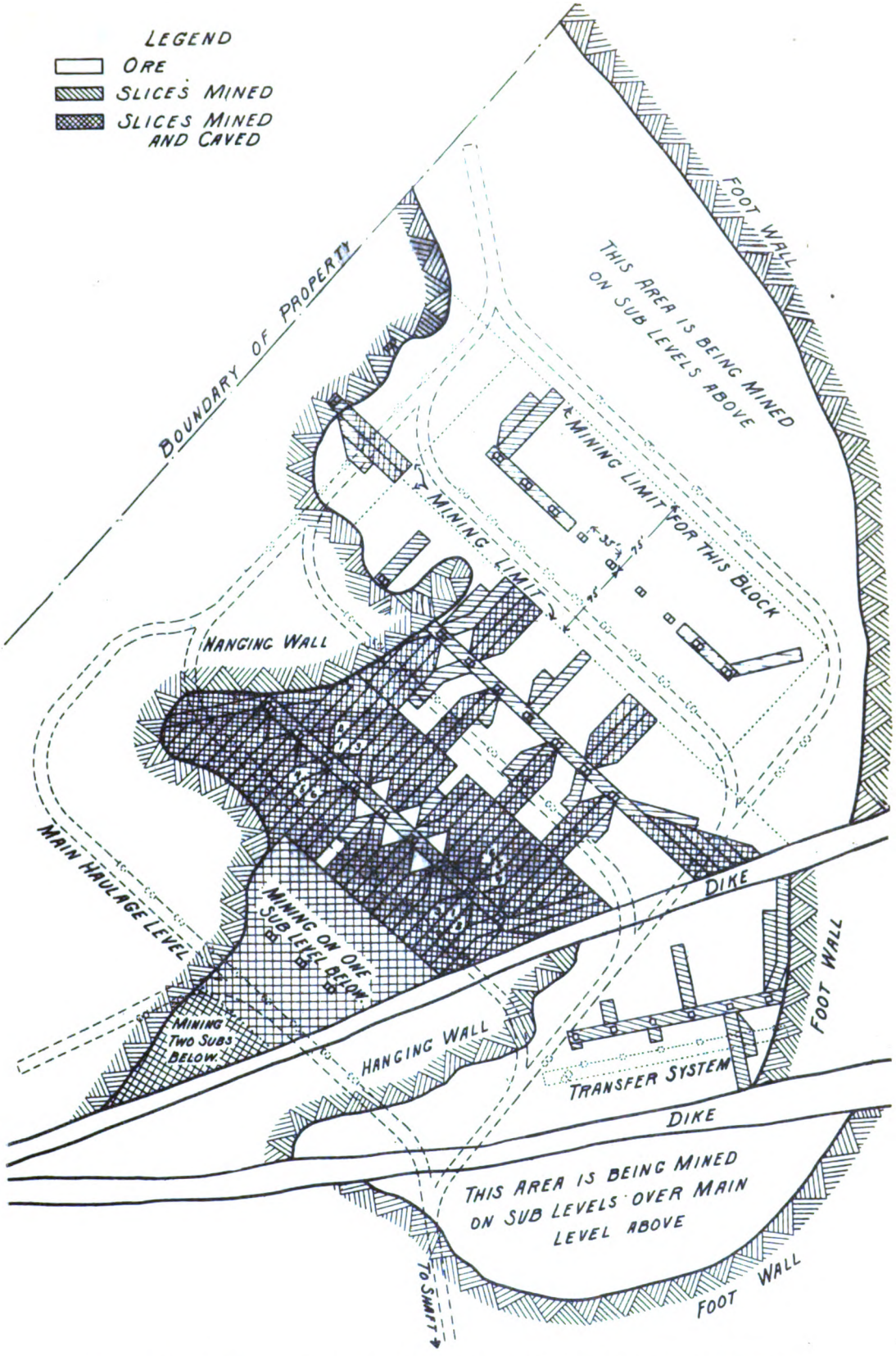

Figure 3.- Typical sublevel, showing division into blocks, method of development of blocks, and arrangement of slices in blocks. Small numbers indicate sequence of slices. Step succession of caving

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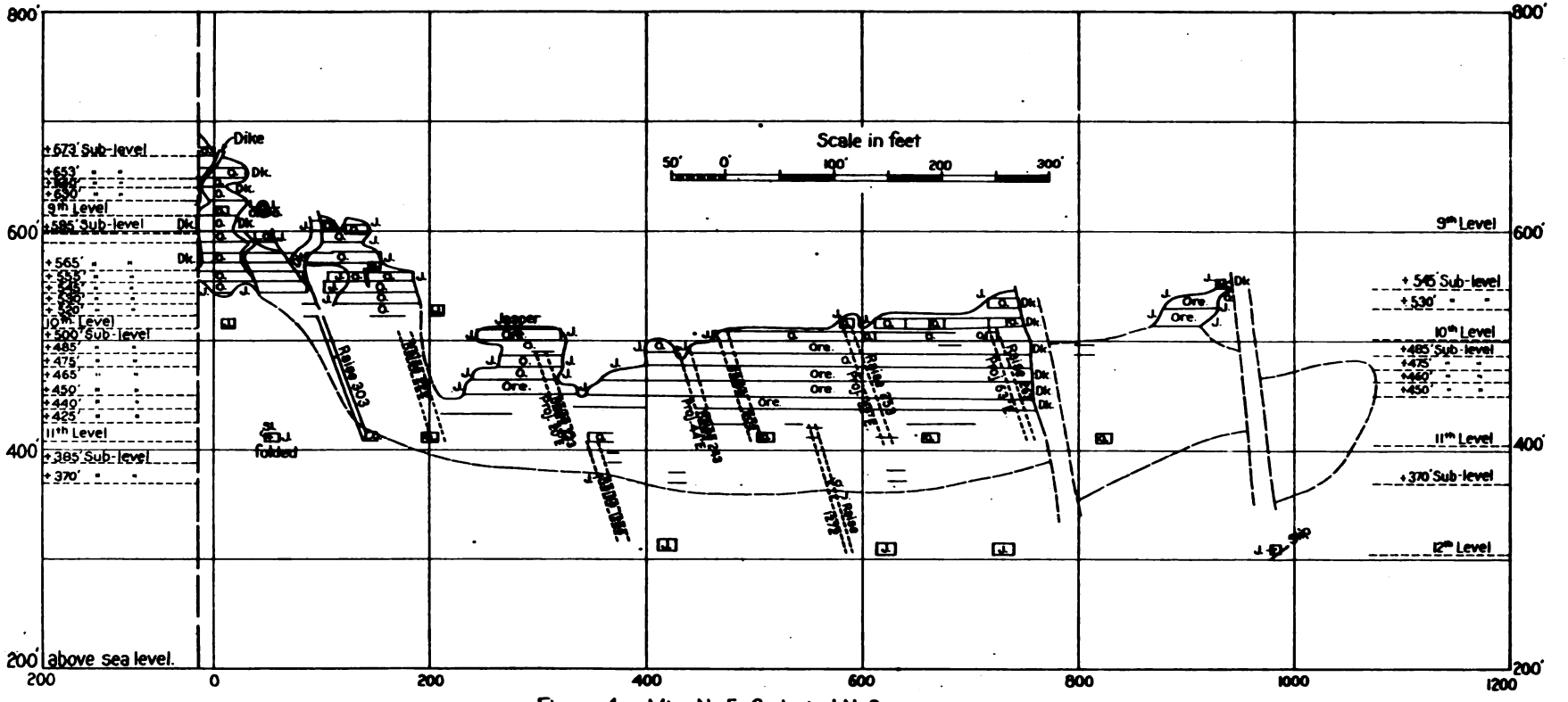

Figure 4.- Mine No.5. Geological N-S. cross section on 400 feet looking east.

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advancing under new hanging wall or where ground is left in the back, three pieces of 40-pound rail about 10 feet long are used alongside the forepoles. During the last two years much attention has been paid to the covering of the floor of each sublevel drift. Poles 9½ feet long and 3 to 6 inches in diameter are laid along the drift and are spiked to three crosspieces. Under new hanging wall or near dikes or horses of jasper these poles are placed close together and covered with cross lagging to protect the next sublevel from runs of rock. Where there is a good mat overhead the poles are spaced 6 to 8 inches apart. These poles form a good floor for scrapers to ride upon and are an excellent covering to work under on the sublevel below. Wire netting is now being spread over the covering poles in new territory, particularly under new hanging wall, to make a more secure mat.

A sublevel interval of 10 to 11 feet was used formerly; this has lately been increased to 12 to 13 feet. This increase followed the adoption of the methods of covering down described above. The length of legs has also been increased from 8 to 9 feet so as to decrease the amount of blocking required between the caps and the mat. These changes are of necessity being adopted gradually, as conditions permit, and within a year will be in effect throughout the entire mine. All working places are supplied with extension cords with 50-watt lamps attached to facilitate scraping operations and increase safety. Chutes at raises are guarded with grizzlies made of rails set 10 inches apart. When scraping is not in progress the chute is covered with the scraper or with plank.

During the last four years the use of scrapers has increased, so that now all of the ore is handled by this means on the sublevels. Electric double-drum scraper hoists of 15 hp. capacity are standard equipment for the mine. There are a considerable number of smaller electrical units and air-operated hoists still in use, but these are gradually being replaced with the larger units. A box-type scraper equipped with manganese lip is used (fig. 5), having a 36-inch maximum width and a 33-inch cutting edge, the sides tapering both toward the bottom and the front. This style has been developed at this property as the most satisfactory shape for handling the ore. One-half-inch and three-eighths-inch ropes are used throughout the mine for pull and return ropes. The use of scrapers is seriously handicapped by the presence of water, and in those portions of the mine where water is encountered special attention has to be paid to the sequence of slices so that the water may be drained off as far as possible from the working places.

TRANSFER DRIFTS

The flat foot wall (15°) presents a problem in main-level layout to reduce the amount of rock drifting and raising necessary to extract the ore without extraordinarily long scraper hauls on the sublevels. When ore was moved by hand shoveling and buggies not as much attention was paid to the length of haul, but with scraper hoists it is desirable to avoid a long pull that interferes with the completion of a cycle on each shift. To take care of this situation a transfer system was inaugurated about two years ago and has worked out very satisfactorily. This is merely a sublevel drift above the main level at a location where there is a minimum amount of rock raising and rock drifting for the amount of ore adjacent thereto. The drifts lead off from a single raise that has room for eight or more motor cars of ore. These transfer drifts vary in length, with 300 feet as a maximum, and are equipped with 25-hp. electric double-drum scraper hoists and a 48-

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inch scraper built on the same design as those used in sublevel slicing. Three 30-pound rails are laid on ties the length of the drift for the scraper to ride upon. Single-compartment crib raises, 4 feet 2 inches square inside, are put up at 65 to 70° angles at 35-foot centers along the transfer drift. They are placed well over to one side of the drift, so that the ore from the sublevel above does not fill the drift completely, and there is always room for the passage of scraper and attendant by the piles of ore. The drift is well lighted so that the operator can watch the scraper. The sublevel slices from these raises are at right angles to the transfer drift and are similar to those described above, with the exception that often the size of pillar is not as regular as could be desired, owing to the position of the foot or hanging wall. The transfer drift is not used for the handling of timber. Where a large number of contracts are dumping into one transfer system two men are employed, one to operate the hoist and the other to watch the scraper. This transfer system works satisfactorily where the ore is dry but is not practical where much water is encountered. The presence of water does not affect the operation of the transfer itself but results in a delay in loading the ore on the main level. Water makes the ore of Mine No. 5 extremely hard to handle in chutes, as it runs very freely with too much water and becomes very sticky with a very small amount. Chutes often become completely blocked and hold back any free water that may accumulate on top. The opening of these blocked raises almost always involves a run of ore on the main-level tracks, and for this reason as little ore as possible is permitted to accumulate in the raises.

MINING TIMBER

Mining timber is handled on trucks directly from the timber yard on surface to various points on the main levels, where it is piled either in timber stands or along the drift for transportation to the various working places. Where possible, several working places are supplied with timber from one raise, up which the timber is hoisted by the timber handlers. Air hoists are in general use for taking timber up the raises. Care is taken in the transfer of timber on main levels not to interfere with the ore trains.

DRILLING MACHINES

Hand auger-drill machines are used throughout the mine with twist auger-drill steel. The diamond-section auger steel is used in the harder ground, and a larger-flanged section for the softer ore. Drilling occupies one to three hours per shift for the 6 to 14 holes required for a cut. In the harder ground two machines are used by each contract, and more holes are required.

UNDERGROUND HAULAGE

Electric haulage is used throughout the mine on the main levels. Six and ten ton trolley locomotives are used. The track gage is 30 inches with 40-pound rail. Four-ton, 65-cubic feet, saddleback cars have been the standard equipment up to the present time, but these are now being replaced with rocker-dump cars of the same capacity. Trains consist of 7 to 10 cars. At the shaft station each level is equipped with three concrete storage pockets of 50 tons capacity each, which discharge directly into the measuring pockets from which the 5-ton skips are loaded.

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CONTRACT SYSTEM

All miners work on a contract system, the unit price calculation being a 4-ton main-level tram car. Every contract in the mine is provided with a scraper and the contract price per car ranges from $1.10 to $1.80. A few gangs of timbermen are employed on the company-account system of pay. The miners pay for explosives, carbide lamps, and other small supplies. The company furnishes drill machines, drill steel, compressed air, electricity, loading equipment, and timber. The miners do their own drilling, blasting, timbering, and mucking.

VENTILATION

Ventilation is provided by means of a fan of 100,000 cubic feet capacity, which provides ventilation for No. 5 mine and an adjacent mine operated by the same company. This fan is located in a fireproof building at the collar of the abandoned No. 2 shaft at the east end of the property. The air is forced into the mine and by means of suitable doors and brattices is conducted through No. 5 mine, the operating shaft of which is upcast, as is also the shaft on the adjacent property. In dead ends and in areas where pressure is very heavy on a considerable thickness of mat, auxiliary booster fans are in use. Fresh air is drawn from the fresh-air passage on the main-level drift and led through canvas tubing to the sublevel face. Raises used for the passage of air are covered with wire netting, and powerful lights are provided to light the ladder roads in these raises where the manways are used for traveling. Mechanically operated doors are installed on the main levels for locking through motor-haulage trains.

FIRE HAZARDS AND SAFETY WORK

There is always considerable danger from fire in a mine using a large amount of timber, so all known precautions are taken to prevent it. Main-level drifts near the shaft have fireproof self-closing doors that can be closed by counterweights and are held open by latches which can be tripped by opening a valve near the main air line and a special line at any level in the shaft or on surface.

A stench warning-signal system has been installed, which can be introduced to all working places through the air lines.

Fire-helmet crews receive regular training from both the company's safety department and the United States Bureau of Mines rescue car.

A large number of men at the property have received training in first-aid work; most of them have also received certificates from the United States Bureau of Mines.

Smoking is prohibited in the mine, in the timber tunnel to shaft, and in the timber yard.

Great attention is given at this property to safety work, and excellent records have been made.

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Especial attention is paid to cleanliness underground and on surface. This work is assisted by having all places well lighted. Discipline is strictly enforced, as this is one of the most important features in promotion of safety.

All shaft stations are whitewashed and well lighted. The haulage drifts through rock to the ore body are lighted, as well as all chutes and switches in the ore body.

The wearing of hard hats is obligatory. Goggles and gloves must also be worn when certain classes of work are being done. Hard-toed boots have been adopted as standard for the mine and will be worn by all men within a short time.

All fuses are capped at a special station on the surface and delivered to the miners in metal containers lined with tarred paper. Powder is distributed from fireproof magazines underground.

Many other safety rules and practices have been introduced and made standard. It is intended that each man in the mine shall know what is required of him in his work in order that he follow the best practice for safety and efficiency.

MINING COSTS

Table 1 - Summary of costs

Name or number of mine:-Mine No. 5, Marquette County, Mich. Period covered:-Year 1929. Tons ore hoisted during period:- 555,919. Mining method:-top-slicing.

Underground costs per ton of ore hoisted

	1	2	3	4	5	6	7	8
	Labor	Super-vision	Compressed-air drills and steel	Power Cost	Explo-sives	Timber	Other Supplies	Total
Development:								
In ore	$0.019	$0.001	$0.003		$0.004	$0.003	$0.002	$0.032
In rock	.013	.001	.002		.003		.001	.020
Mining	.421	.018	.095	$0.008	.055	.079	.063	.739
Transportation (underground)	.126	.004		.049			.031	.210
General underground expense	.020	.006					.064	.090
Surface expense (directly applicable to underground operation)	.004							.004
Total	.603	.030	.100	.057	.062	.082	.163	1.095

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Table 2 - Summary of costs in units of labor, power and supplies

Name or number of mine:- Mine No. 5, Marquette County, Mich. Period covered:- Year 1929. Tons ore mined and hoisted:- 555,919. Mining method:- Top slicing.

	Development	Mining (Stoping)	Total
A. Labor (man-hours per ton)			
Breaking (drilling and blasting)	0.011	0.093	0.104
Timbering	.031	.276	.307
Mucking (scraping)	.019	.164	.183
Haulage and hoisting	.017	.155	.172
Supervision	.003	.029	.032
General	.010	.095	.105
Total labor underground	.091	.812	.903
Avg. tons per man per shift - surface			36.43
Avg. tons per man per shift - underground			8.87
Avg. tons per man per shift - surface and underground			7.13
Labor, per cent of total cost			58.2%
B. Power and supplies			
Explosives (lbs. per ton)	0.036	0.372	0.408
(kind and grade)	50 and 60 per cent L. F.	50 and 60 per cent L. F.	
Timber (lin. ft. per ton of ore)			.6723
Total power (in kw. h. per ton)			
(1) Air compressors			4.49
(2) Hoisting			2.78
(3) Pumping			3.96
(4) Lighting and haulage			.60
(5) Miscellaneous			.66
Total power, Kw. h. per ton			12.49
C. Per cent of total cost	10.00	90.00	100.00

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Table 3 - Detail of costs in units of labor, power, and supplies

DEVELOPMENT

	Drifting	Crosscutting	Raising
Size of excavation:			
Main levels - rock drift	8 by 9 ft.	8 by 9 ft.	
Main levels - ore drift	10 by 10 ft.	10 by 10 ft.	6 by 11 ft.
Timbered or not	10 by 10 ft.	ore drifts, timbered	Timbered
	8 by 9 ft.	rock drifts, not timbered	
Physical properties of ore	Firm - requires drilling and blasting		

	Main level - ore and rock drifting
A. Labor (man-hours per foot):	
Breaking (drilling and blasting)	1.55
Timbering	1.92
Mucking	2.83
Haulage and hoisting	1.20
Supervision	.22
Total labor	7.72
Feet per 8-hour man-shift	1.04
B. Power and supplies (per foot):	
Explosives (lbs. per ft.) in large drifts	20.2
C. Percentage of total cost:	
Labor	75.4
Supplies	24.6

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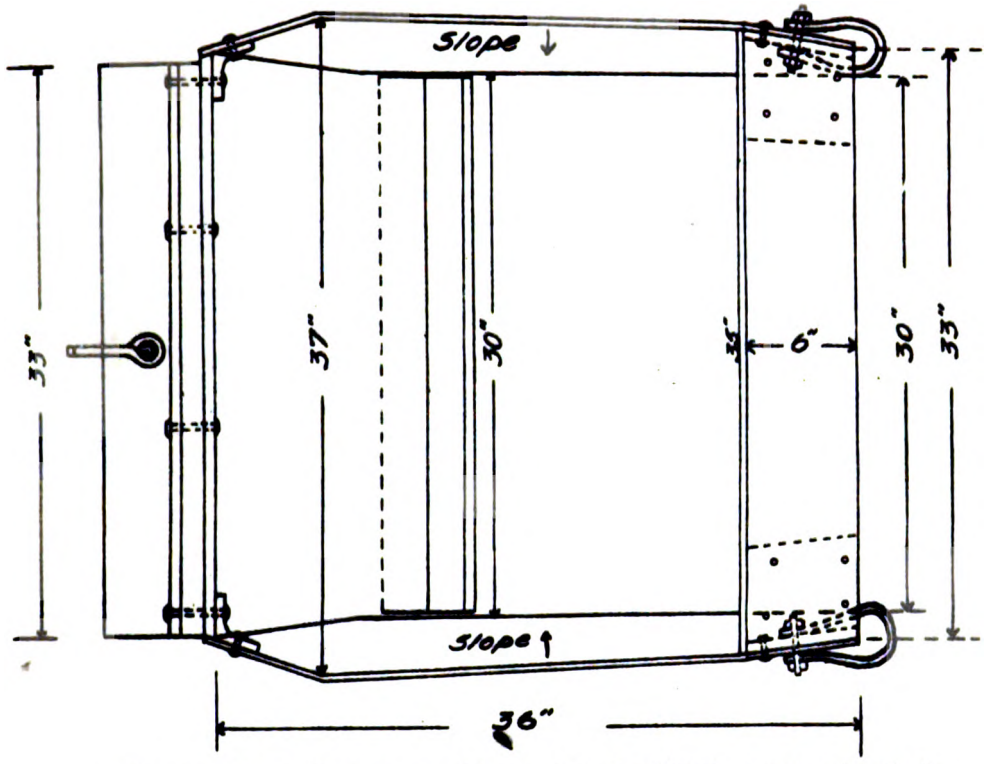

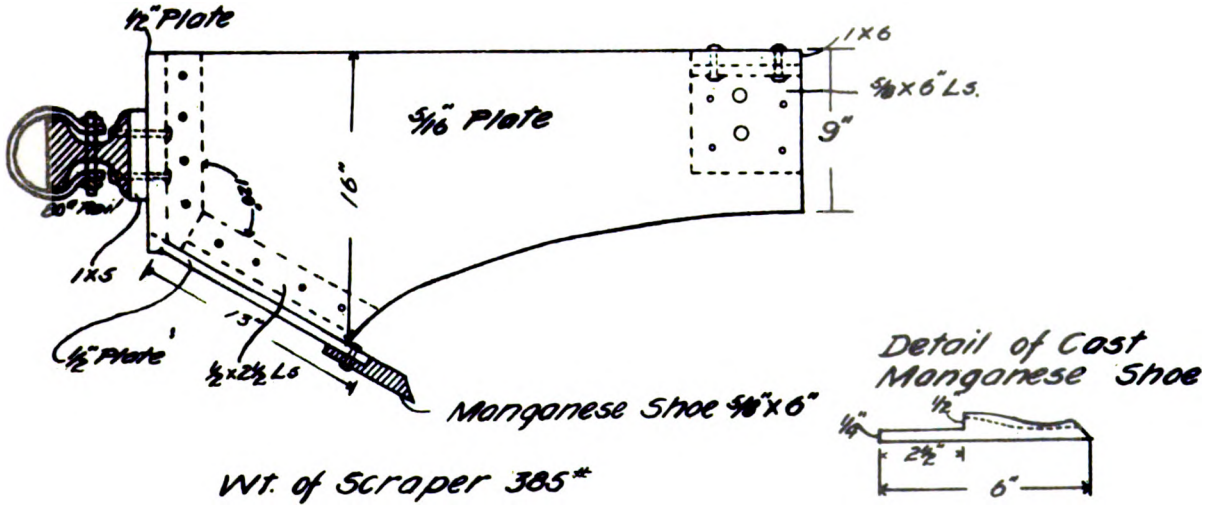

33" Scraper used with Hoists to 10 H.P.
39" " " " " of 15 "

Figure 5.- Sketch of 33-inch scraper used at mine No. 5 Marquette range

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